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Iki et al.

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(54) **STATOR FOR ELECTRIC ROTARY MACHINE**

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CPC .. ***H02K 3/12*** (2013.01); ***H02K 3/28*** (2013.01); ***H02K 3/345*** (2013.01); ***H02K 3/50*** (2013.01); ***H02K 9/22*** (2013.01); ***H02K 15/0414*** (2013.01); *H02K 15/0025* (2013.01); *H02K 15/0081* (2013.01)

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USPC 310/DIG. 6, 71, 201, 215
See application file for complete search history.

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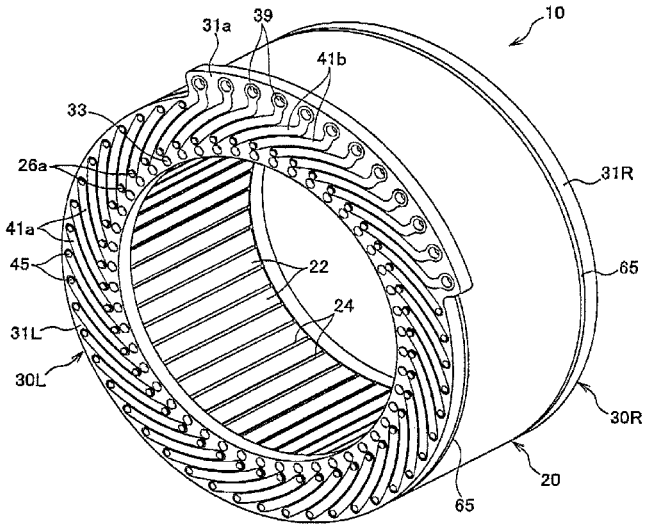
(57) **ABSTRACT**

A stator for an electric rotary machine includes: a stator core having a plurality of slots; and segmented coils of a plurality of phases (for example, coils **50** in the embodiment), wherein: the segmented coils of a plurality of phases have pluralities of coil bars which are inserted individually in the plurality of slots in the stator core and which extend substantially in a straight line and pluralities of connection coils which connect together the coil bars of the same phase to thereby make up extending portions; the connection coils each comprise an inner connection coil and an outer connection coil which are disposed in different axial positions; and the inner connection coil faces an outer connection coil of a different phase in an axial direction and the outer connection coil faces the inner connection coil of a different phase in the axial direction.

7 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

H02K 3/34	(2006.01)
H02K 9/22	(2006.01)
H02K 15/04	(2006.01)
H02K 3/50	(2006.01)
H02K 15/00	(2006.01)

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FIG. 1

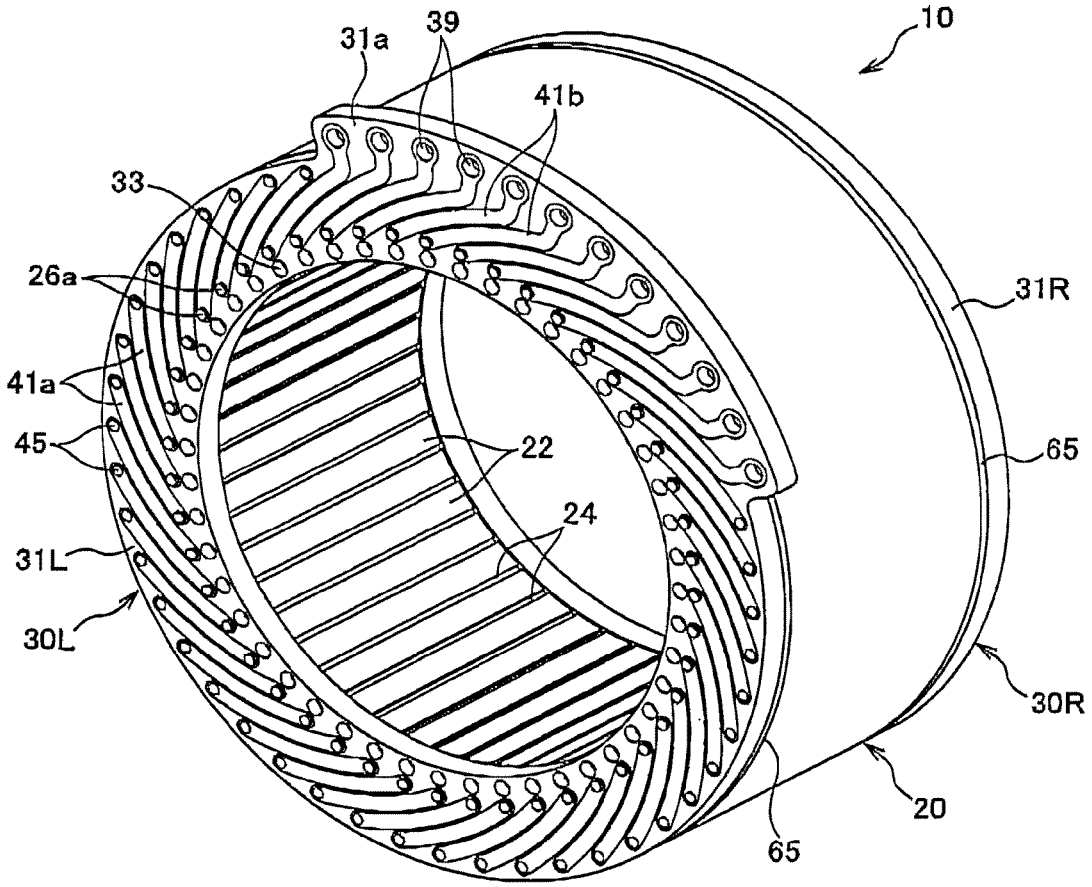


FIG. 2

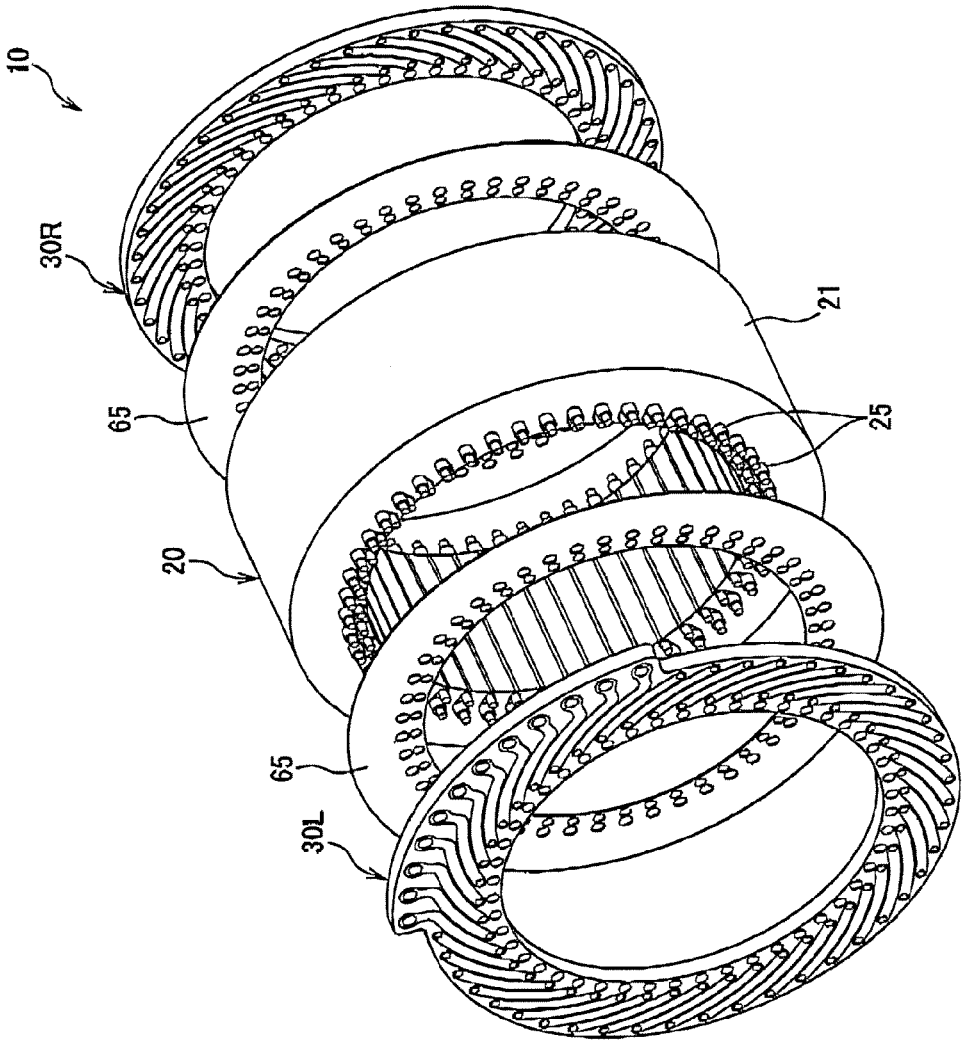


FIG. 3A

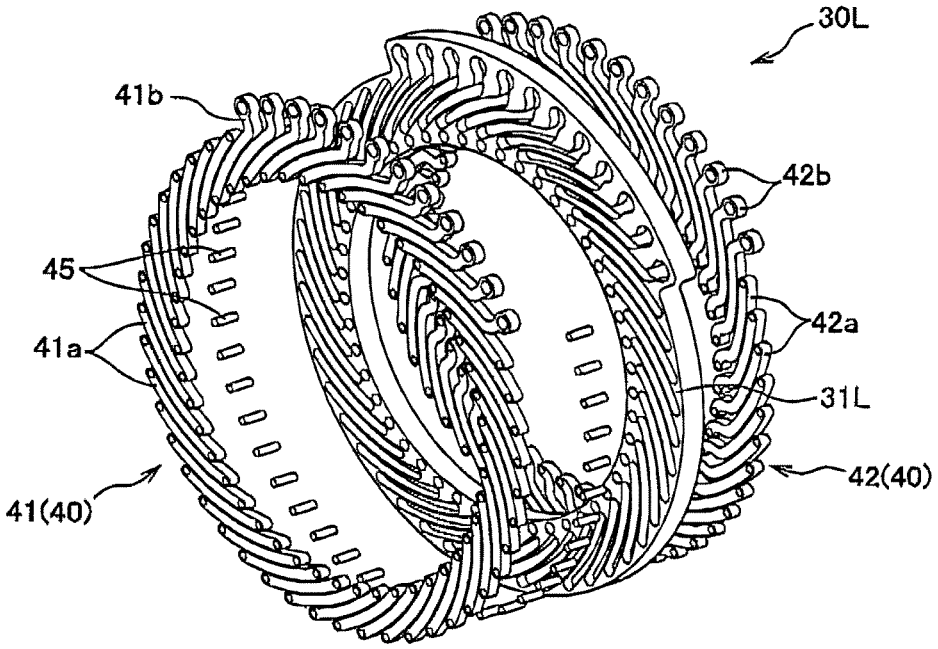

30L
41b
42b
45
42a
41a
31L
42(40)
41(40)

FIG. 3B

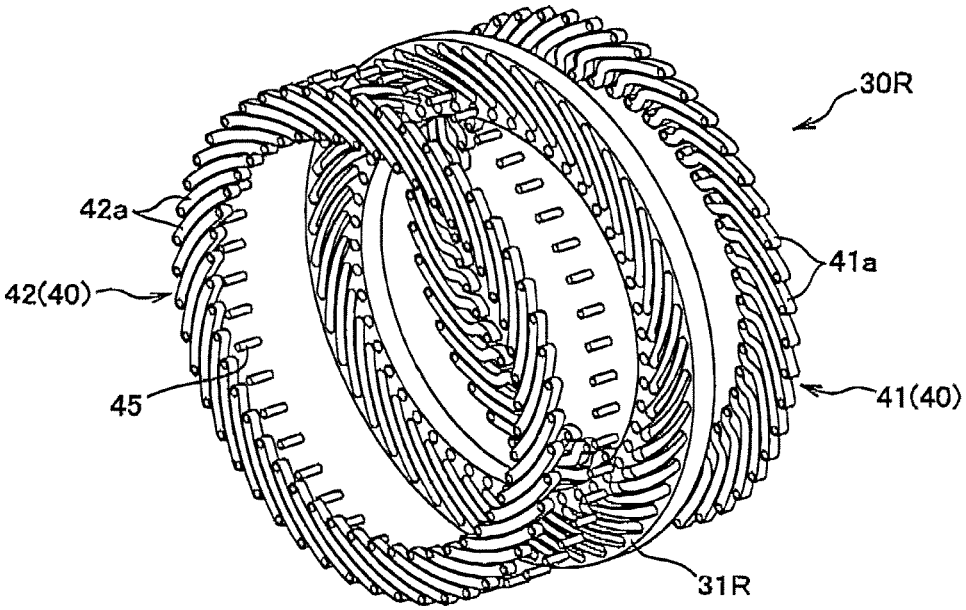

30R
42a
41a
42(40)
45
41(40)
31R

FIG. 4

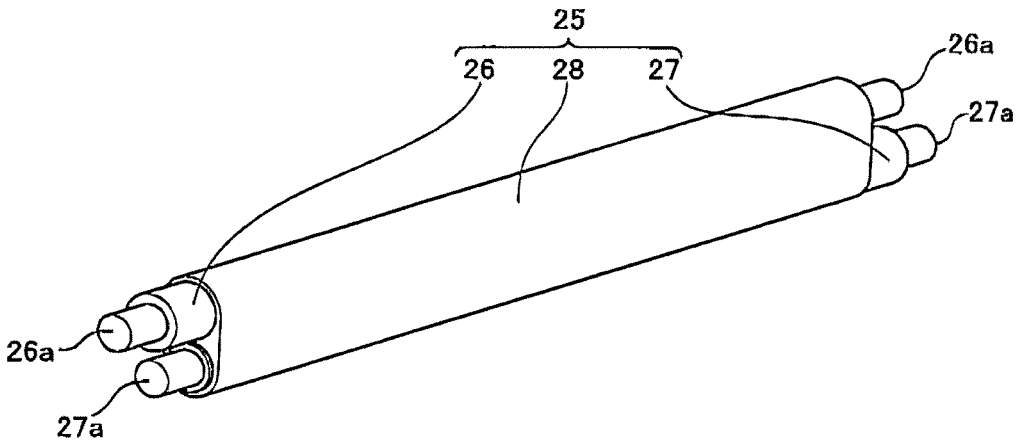


FIG. 5

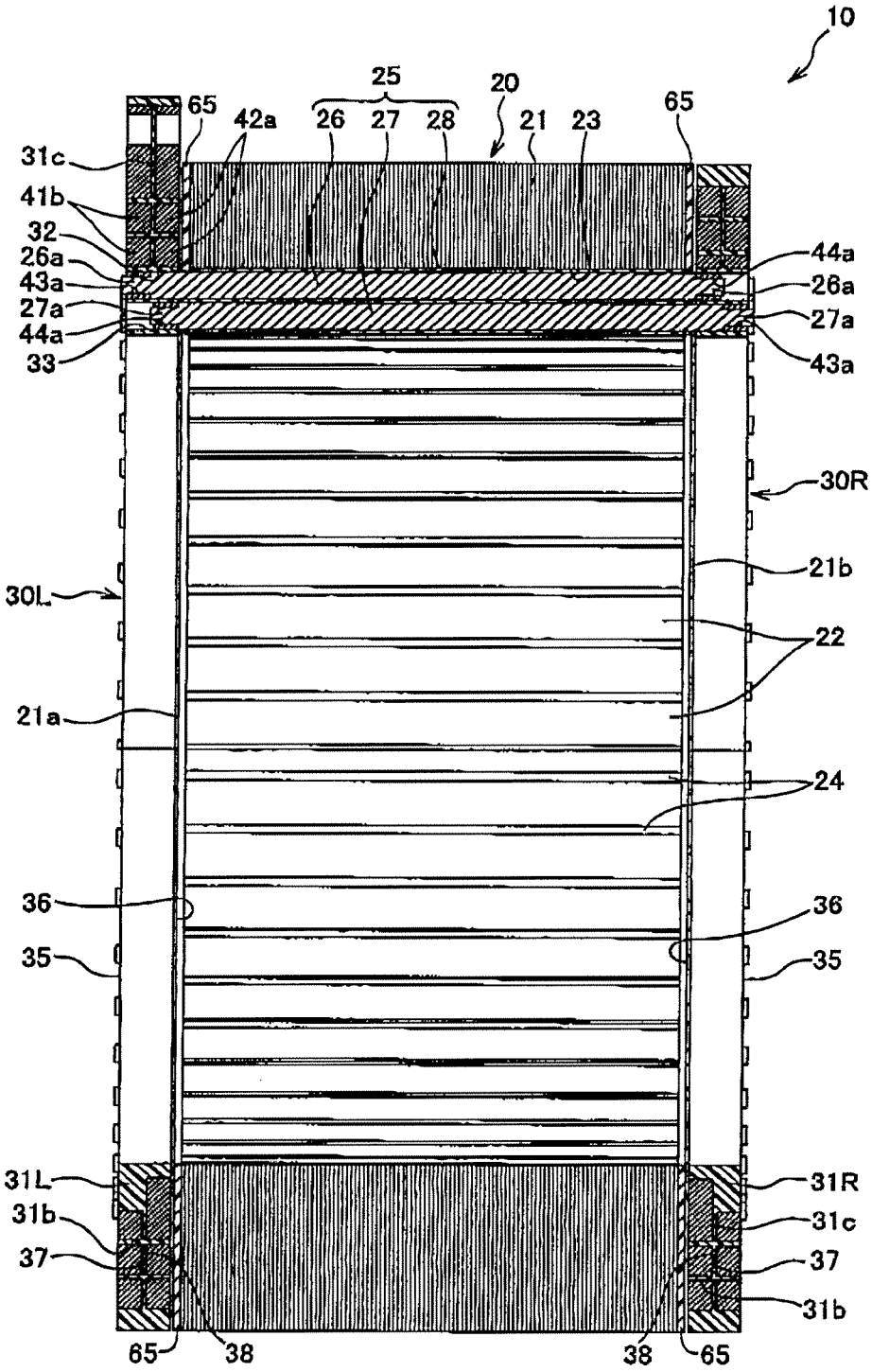

10
25
20
65
42a
26
27
28
21
23
65
31c
41b
32
26a
43a
27a
44a
33
44a
26a
27a
43a
30R
21b
30L
22
21a
24
36
36
35
35
31L
31R
31b
31c
37
37
31b
65
38
38
65

FIG. 6

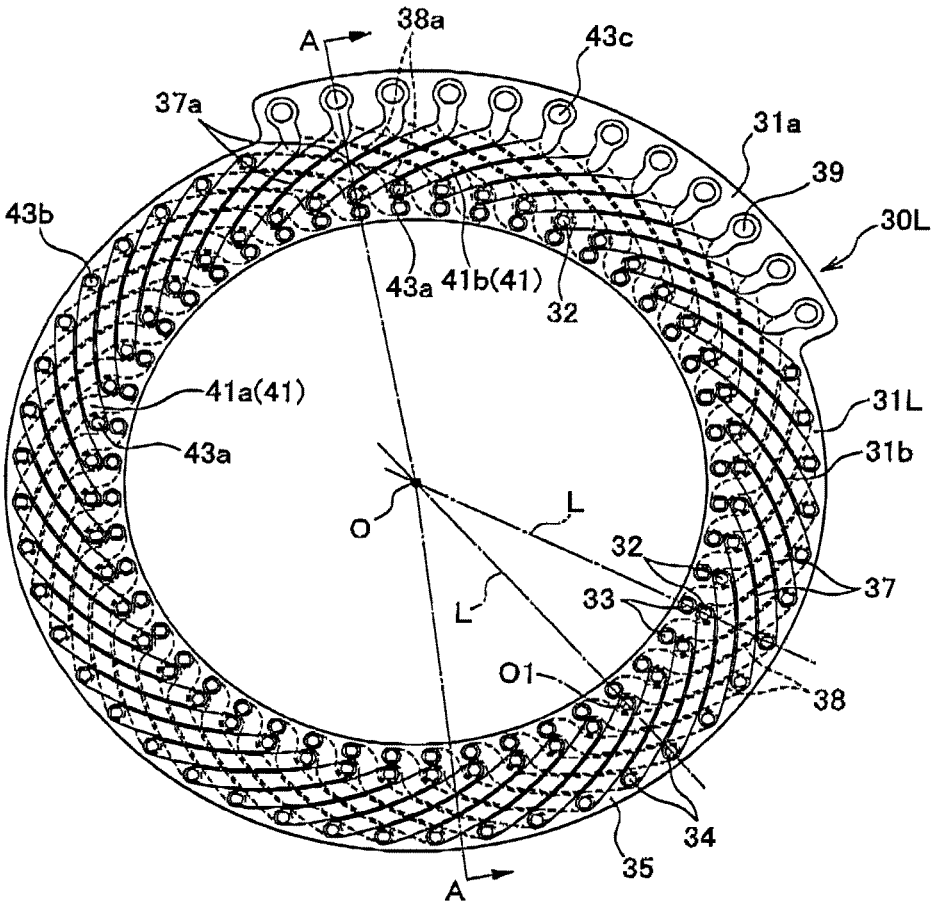

A
38a
43c
37a
31a
39
43b
30L
43a
41b(41)
32
41a(41)
31L
43a
31b
O
L
32
37
L
33
O1
38
34
35
A

FIG. 7

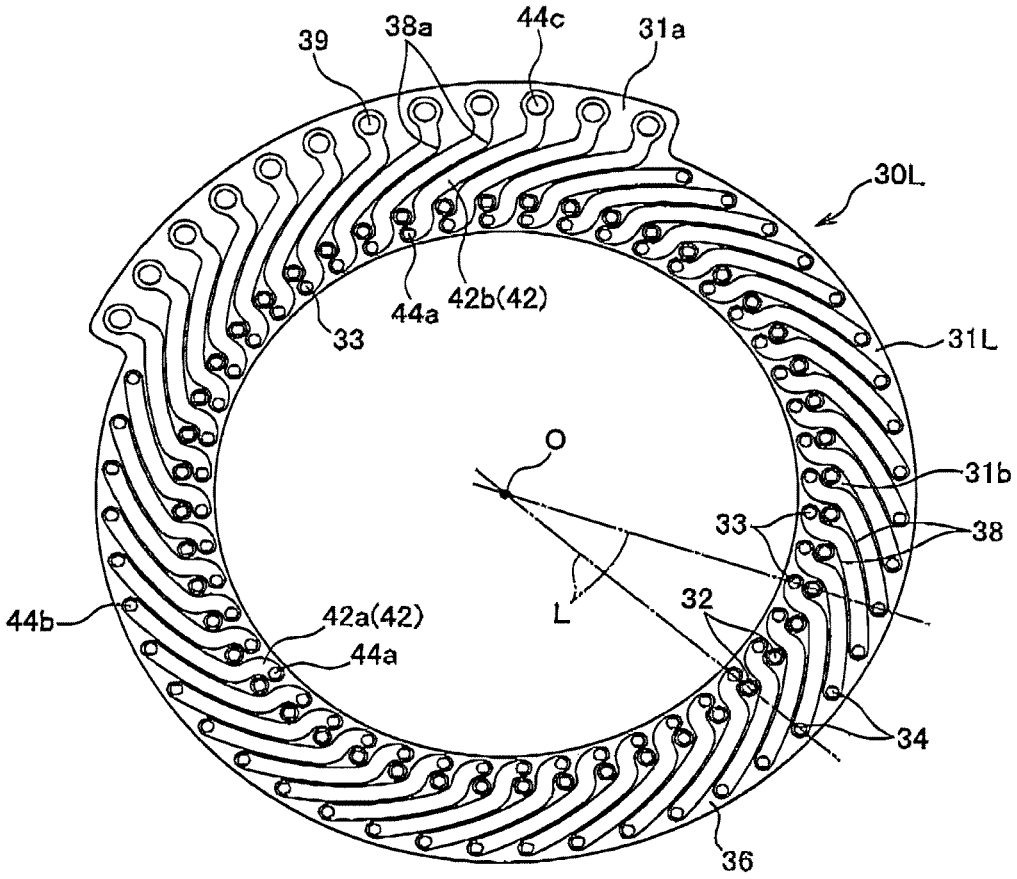

39
38a
44c
31a
30L
44a
42b(42)
33
31L
O
31b
33
38
L
32
44b
42a(42)
44a
34
36

FIG. 8

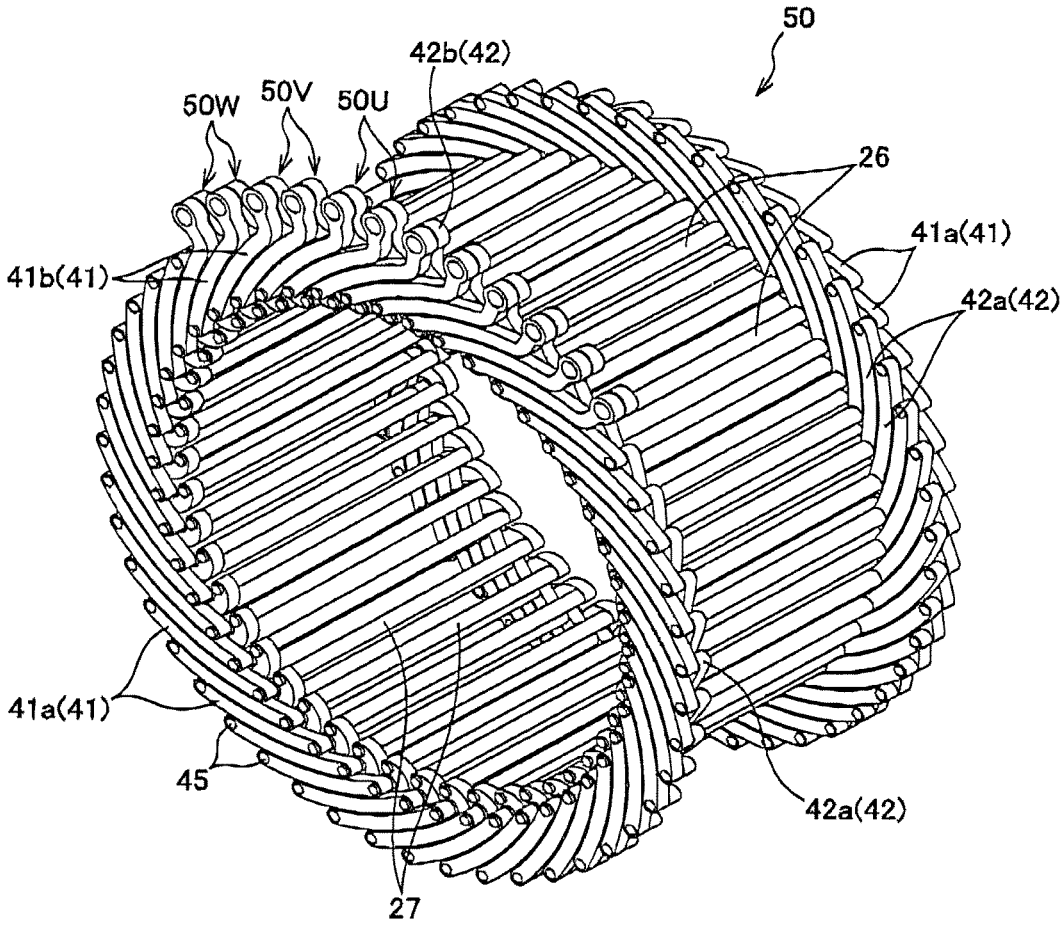


FIG. 9

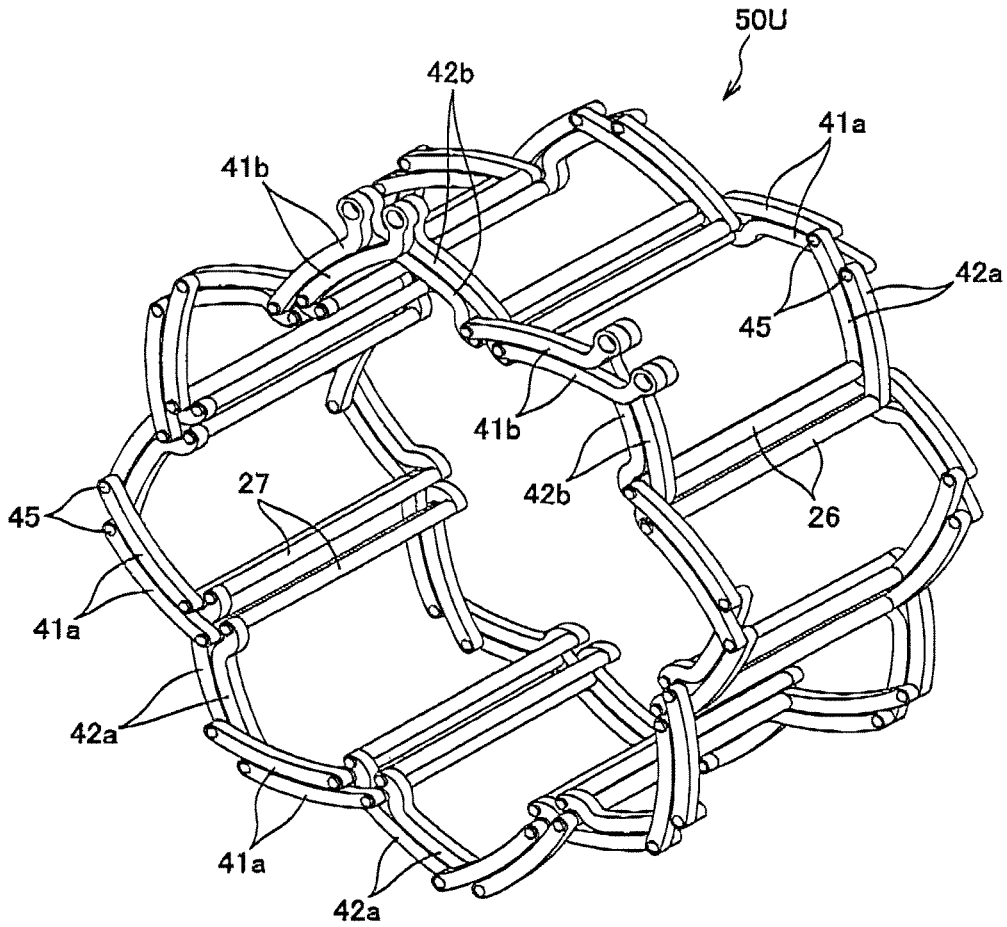


FIG. 10

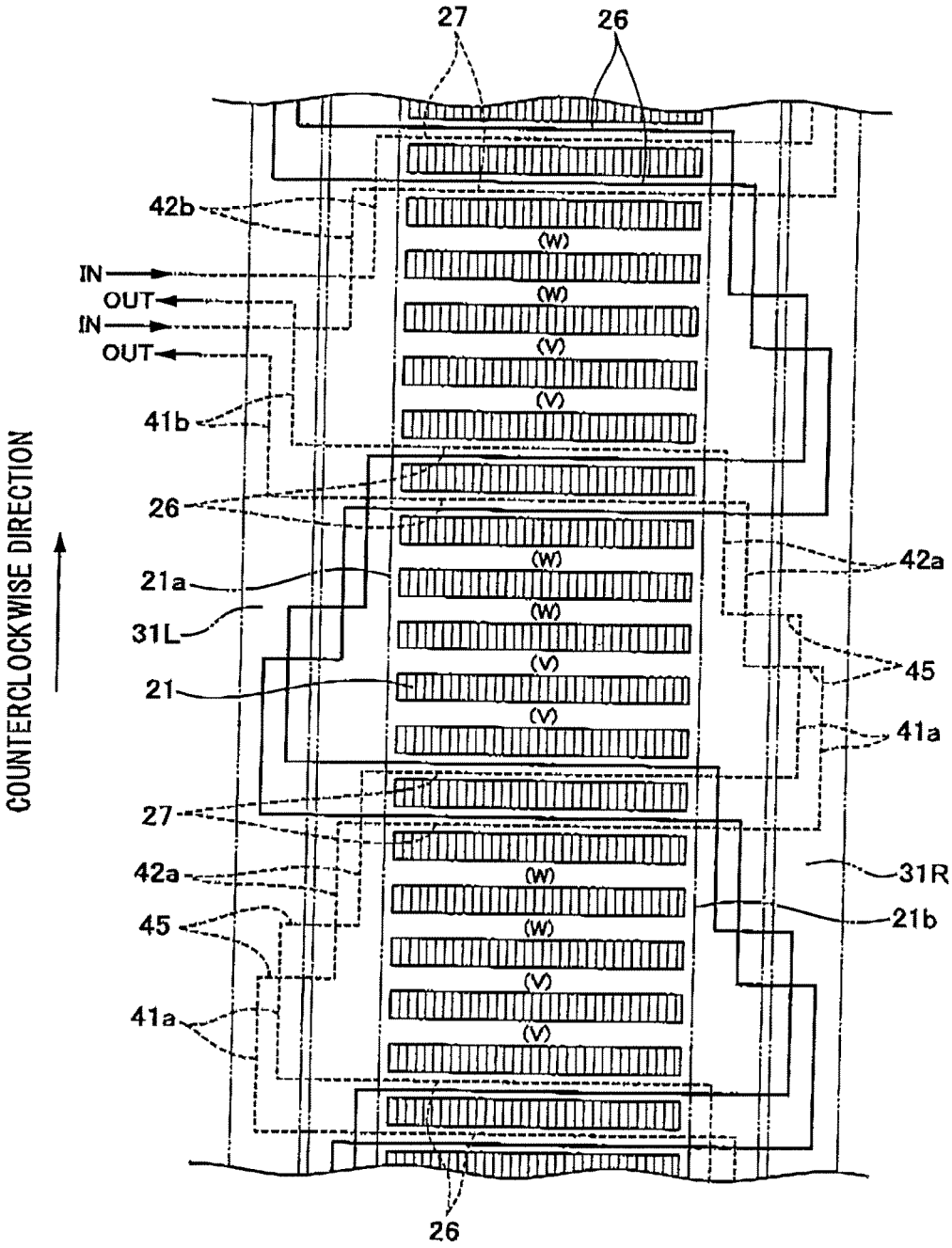

27
26
42b
IN
OUT
IN
OUT
41b
26
21a
31L
21
27
42a
45
41a
26
(W)
(V)
COUNTERCLOCKWISE DIRECTION
42a
45
41a
31R
21b

FIG. 11A

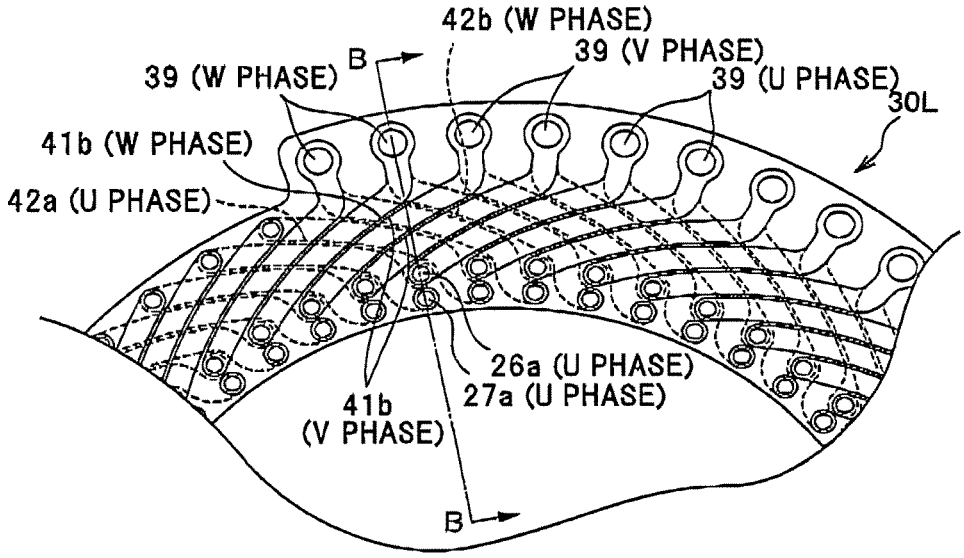


FIG. 11B

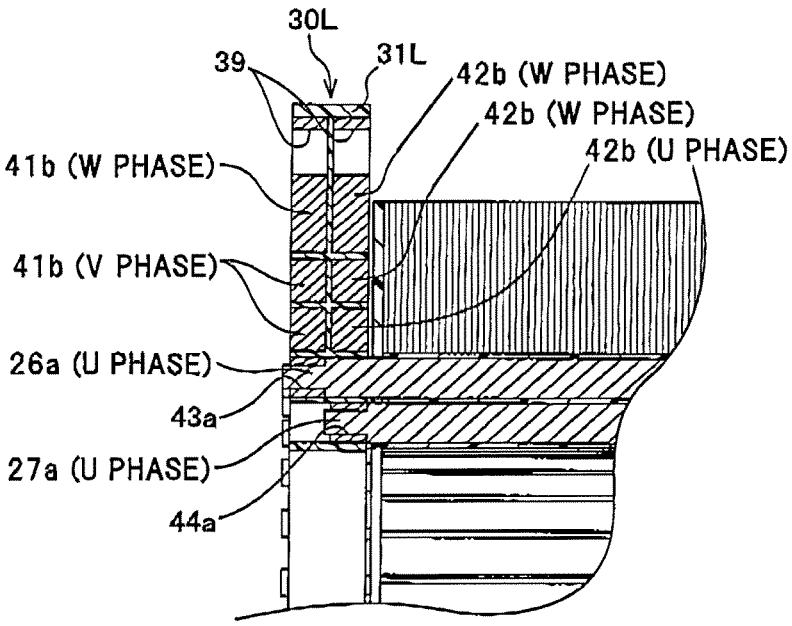


FIG. 12A

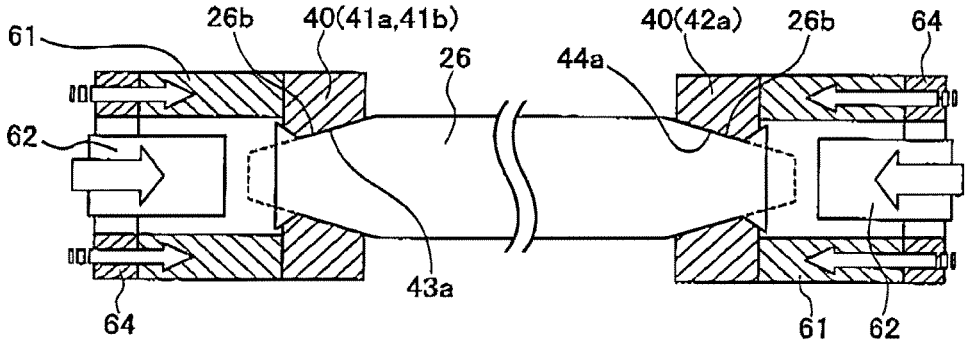


FIG. 12B

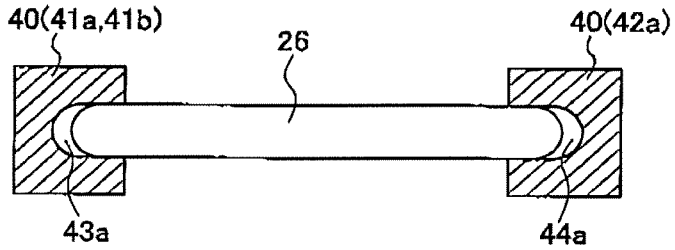


FIG 12C

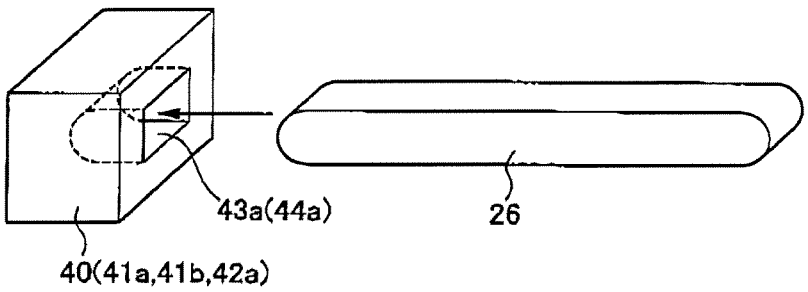


FIG. 13

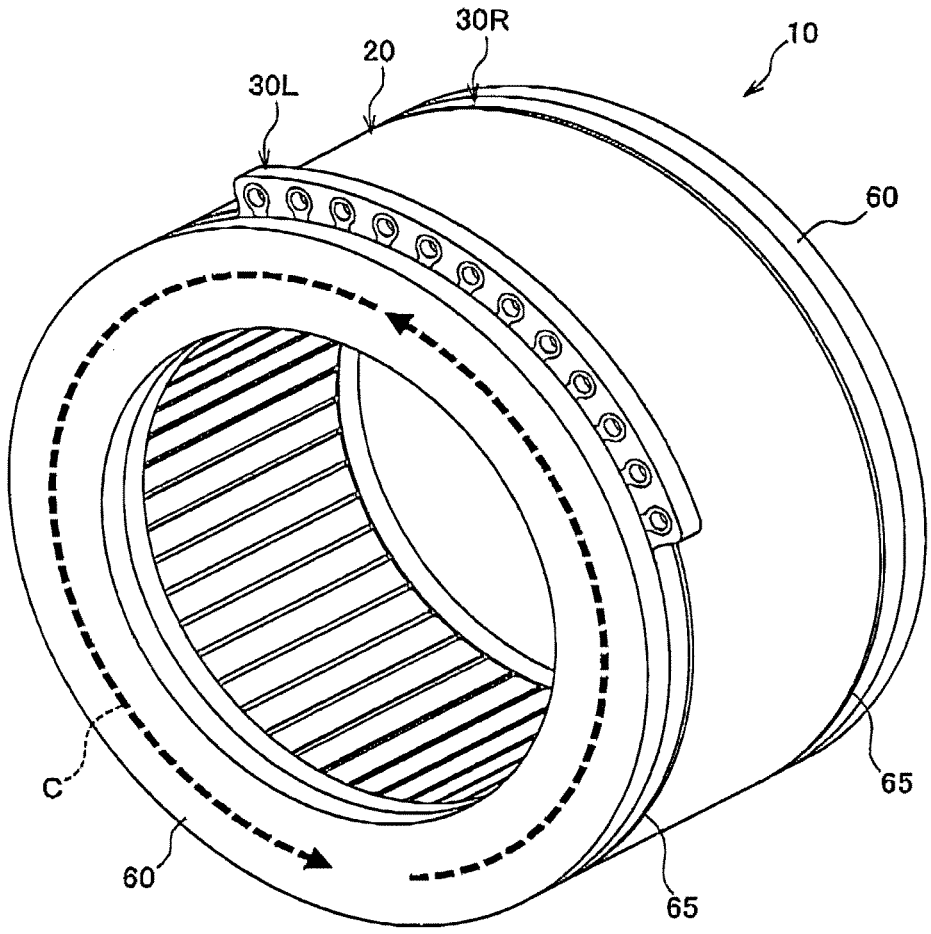


FIG. 14

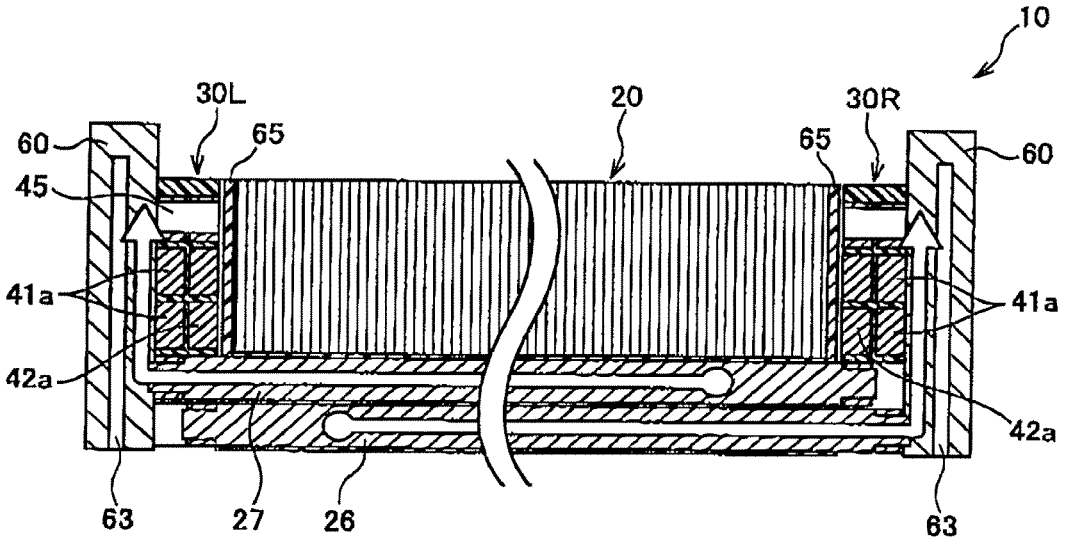


FIG. 15

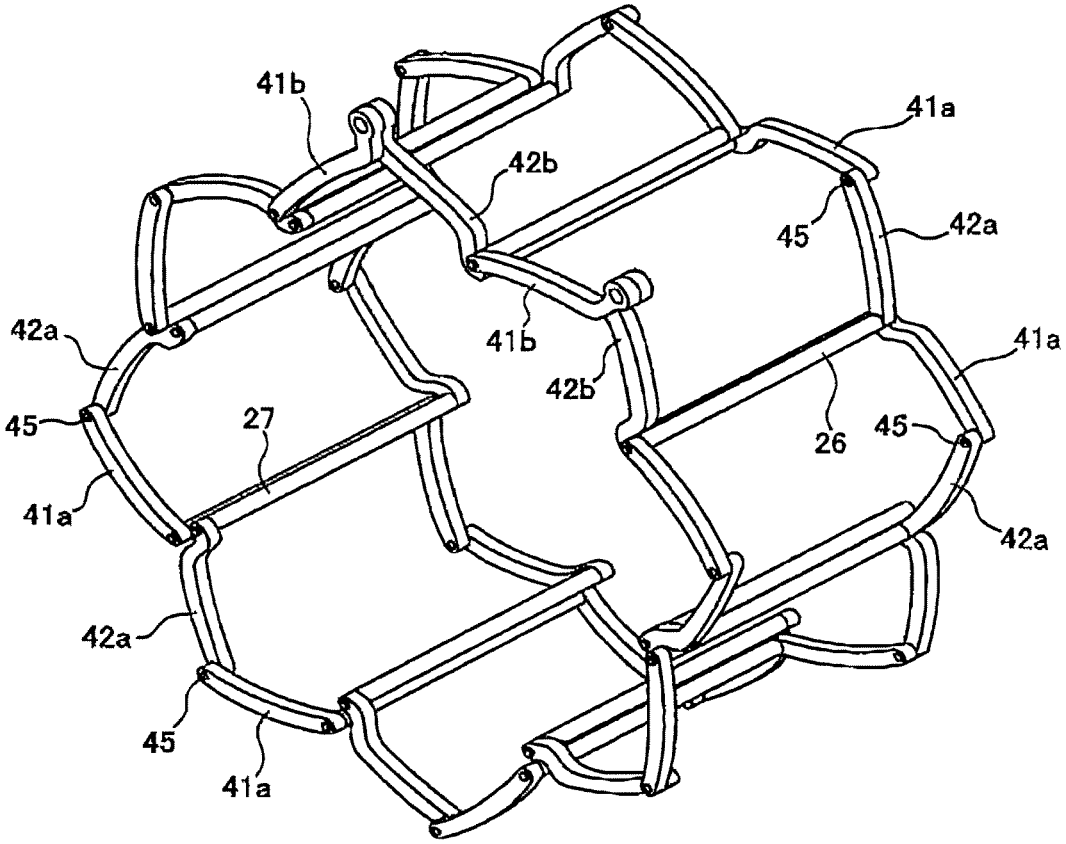
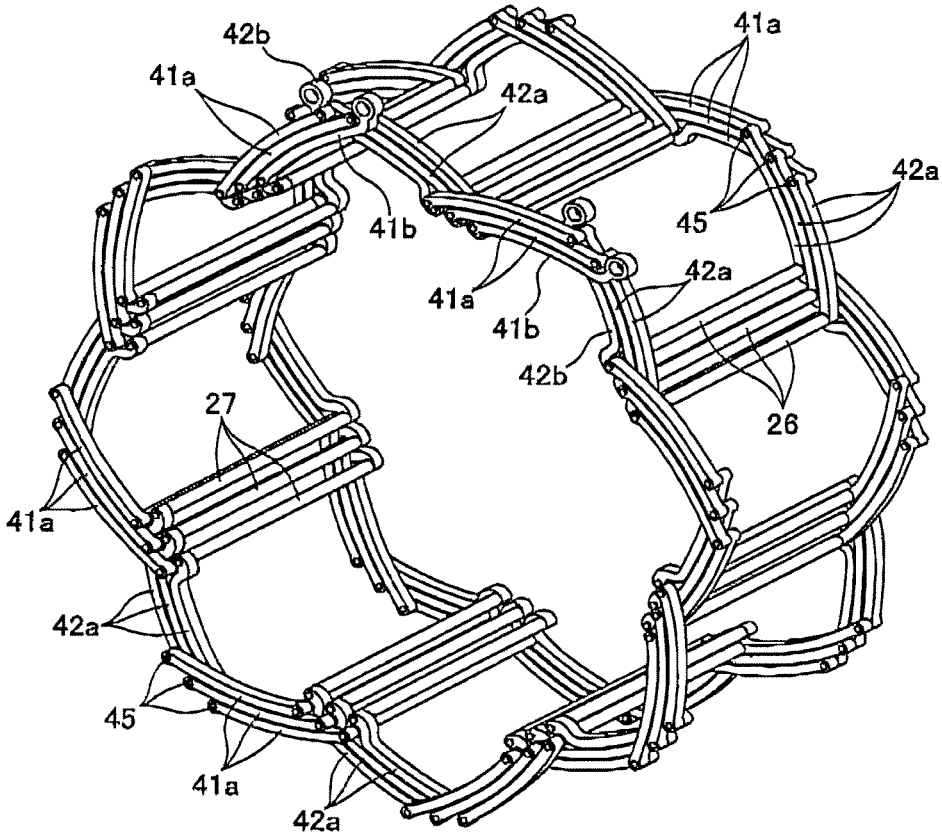


FIG. 16


42b
41a
41a
42a
41b
45
42a
41a
41b
42a
42b
26
27
41a
42a
45
41a
42a

STATOR FOR ELECTRIC ROTARY MACHINE

BACKGROUND

1. Field of the Invention

The present invention relates to a stator for an electric rotary machine which is installed in an electric vehicle or a hybrid vehicle.

2. Description of the Related Art

Conventionally, as a stator for an electric rotary machine which is fabricated using segment coils, there have been known stators for electric rotary machines in which coils are formed by inserting plural segments which are made up of electric conductors which are formed into a U-shape in slots in a stator core, thereafter bending leg portions and joining together end portions of the segments (refer to JP-A-2003-158840 and U.S. Pat. No. 6,894,417).

In stators for electric rotary machines described in JP-A-2003-158840 and U.S. Pat. No. 6,894,417, coils are formed through a forming operation of forming electric conductors into a U-shape, a bending operation of bending leg portions and a joining (welding) operation of joining together end portions of the electric conductors. Because of this, the end portions of the electric conductors are joined together in such a state that the end portions project in the axial direction, and therefore, the size of the stator is increased in the axial direction due to extending portions, and the length of the extending portions is increased. Thus, there still exists room for improvement.

SUMMARY

The invention has been made in view of the problems described above, and an object thereof is to provide a stator for an electric rotary machine which can be reduced in size by suppressing the projection of extending portions in the axial direction and which can enhance the performance thereof by suppressing the copper loss as a result of the length of the extending portions being reduced.

With a view to attaining the object, according to a first aspect of the invention, there is provided a stator (for example, a stator **10** in an embodiment which will be described later) for an electric rotary machine including:

a stator core (for example, a stator core **21** in the embodiment) having plural slots (for example, slots **23** in the embodiment); and

segmented coils of plural phases (for example, coils **50** in the embodiment), wherein

the segmented coils of plural phases have plural coil bars (for example, coil bars **25** in the embodiment) which are inserted individually in the plural slots in the stator core and which extend substantially in a straight line and plural connection coils (for example, connection coils **40** in the embodiment) which connect together the coil bars of the same phase to thereby make up extending portions, wherein

the connection coils each include an inner connection coil (for example, an inner connection coil **42** in the embodiment) and an outer connection coil (for example, an outer connection coil **41** in the embodiment) which are disposed in different axial positions, and wherein

the inner connection coil faces an outer connection coil of a different phase in an axial direction and the outer connection coil faces the inner connection coil of a different phase in the axial direction.

According to a second aspect of the invention, there is provided a stator core for an electric rotary machine as set forth in the first aspect, wherein

a pair of base plates (for example, base plates **31**L, **31**R in the embodiment) are provided at both ends of the stator core, wherein

in each of the pair of base plates, plural grooves (for example, outer surface grooves **37** and inner surface grooves **38** in the embodiment) are formed on each of an outer surface (for example, an outer surface **35** in the embodiment) and an inner surface (for example, an inner surface **36** in the embodiment) thereof which face each other, wherein

the outer connection coils are disposed in the grooves (for example, the outer surface grooves **37** in the embodiment) which are formed on the outer surface, and wherein

the inner connection coils are disposed in the grooves (for example, the inner surface grooves **38** in the embodiment) which are formed on the inner surface.

According to a third aspect of the invention, there is provided a stator for an electric rotary machine as set forth in the first or second aspect, wherein

the coil bars which are inserted individually in the slots each include a radially outer coil bar (for example, a radially outer coil bar **26** in the embodiment) and a radially inner coil bar (for example, a radially inner coil bar **27** in the embodiment) which are aligned in a radial direction, wherein

one of the radially outer coil bar and the radially inner coil bar is connected to the outer connection coil at one end and is connected to the inner connection coil at the other end thereof, and wherein

the other of the radially outer coil bar and the radially inner coil bar is connected to the inner connection coil at one end and is connected to the outer connection coil at the other end thereof.

According to a fourth aspect of the invention, there is provided a stator for an electric rotary machine as set forth in the third aspect, wherein

the outer connection coil connected to the radially outer coil bar at the one end thereof extends radially outwards and in one of a clockwise direction and a counterclockwise direction to thereby be connected to an inner connection coil of the same phase, wherein

the inner connection coil connected to the radially outer coil bar at the other end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to an outer connection coil of the same phase, wherein

the inner connection coil connected to the radially inner coil bar at the one end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to an outer connection coil of the same phase, and wherein

the outer connection coil connected to the radially inner coil bar at the other end thereof extends radially outwards and in the one of the clockwise direction and the counterclockwise direction to thereby be connected to an inner connection coil of the same phase.

According to a fifth aspect of the invention, there is provided a stator for an electric rotary machine as set forth in the fourth aspect, wherein

in each of the base plates, a radially inner through hole (for example, a radially inner through hole **33** in the embodiment) and a radially outer through hole (for example, a radially outer through hole **32** in the embodiment) in which the radially inner coil bar and the radially outer coil bar which are disposed in the same slot in the stator core are inserted, respectively, are formed so as to be aligned in the radial direction, wherein

the inner connection coil and the outer connection coil which are connected to the radially outer coil bar are formed so as to extend along an involute curve, and wherein

the inner connection coil and the outer connection coil which are connected to the radially inner coil bar are formed so as to extend along an involute curve while being bent at a radially inner end of the involute curve so as to extend radially outwards from the radially inner through hole while extending around the radially outer through hole.

According to a sixth aspect of the invention, there is provided a stator for an electric rotary machine as set forth in any of the third to fifth aspects, wherein

the radially outer coil bar and the radially inner coil bar have the same length.

According to a seventh aspect of the invention, there is provided a stator for an electric rotary machine as set forth in any of the first to sixth aspects, wherein

the plural connection coils are disposed within a region where the stator core is projected in the axial direction.

According to the first aspect of the invention, the extending portions which connect together the coil bars of the same phase are made up of the inner connection coils and the outer connection coils which are disposed in the different axial positions, whereby the axial projection of the extending portions can be suppressed, thereby making it possible to reduce the size of the stator. In addition, the copper loss is reduced as a result of the reduction in length of the extending portions, whereby the efficiency of the electric rotary machine is enhanced.

According to the second aspect of the invention, the inner connection coils and the outer connection coils are disposed in the different axial positions efficiently in such a state that they are isolated from each other by the base plate, whereby not only can the size of the stator be reduced, but also the assembling properties of the segmented coils can be enhanced.

According to the third aspect of the invention, the outer and inner connection coils can be connected to the two coil bars which extend from the slot in the form of a wave winding.

According to the fourth aspect of the invention, the outer and inner connection coils can be connected to the coil bars which extend from the slots radially outwards, whereby the rotor can easily be disposed inside the stator, thereby making it possible to connect the connection coils with the coil bars in the form of a wave winding.

According to the fifth aspect of the invention, the inner connection coils and the outer connection coils do not interfere with each other within the base plate, thereby making it possible to reduce the area occupied by them.

According to the sixth aspect of the invention, the radially outer coil bar and the radially inner coil bar are made to have the same length, so that coil bar parts can be commonized.

According to the seventh aspect of the invention, the radial size of the stator can be reduced, and the rotor can easily be disposed inside the stator.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawing which is given by way of illustration only, and thus is not limitative of the present invention and wherein:

FIG. **1** is a perspective view of a stator for an electric rotary machine according to the invention;

FIG. **2** is an exploded perspective view of the stator shown in FIG. **1**;

FIG. **3**A is an exploded perspective view of one of base plate assemblies shown in FIG. **2**, and FIG. **3**B is an exploded perspective view of the other base plate assembly;

FIG. **4** is a perspective view of a coil bar;

FIG. **5** is a vertical sectional view of the stator shown in FIG. **1** which is taken along the line A-A in FIG. **6**;

FIG. **6** is a front view of the one base plate assembly shown in FIG. **3**A;

FIG. **7** is a rear view of the one base plate assembly shown in FIG. **3**A;

FIG. **8** is a perspective view of double-slot type, segmented coils of plural phases;

FIG. **9** is a perspective view of coils of one phase which are taken out from the coils of the plural phases shown in FIG. **8**;

FIG. **10** is an exemplary diagram showing the configuration of the coils of the plural phases;

FIG. **11**A is a partial enlarged view of FIG. **6**, and FIG. **11**B is a sectional view taken along the line B-B in FIG. **11**A;

FIG. **12**A is an exemplary diagram showing a state in which a coil bar and connection coils are connected together through crimping, FIG. **12**B is an exemplary diagram showing a state in which a coil bar having semi-spherical end portions is connected to connection coils through press fitting, and FIG. **12**C is an exemplary diagram showing a state in which a coil bar having semi-circular end portions and a rectangular cross section is connected to connection coils by being press fitted in holes in the connection coils;

FIG. **13** is a perspective view of the stator in which cooling plates are disposed on end faces of the base plate assemblies;

FIG. **14** is a vertical sectional view of a main part of the stator including the cooling plates shown in FIG. **13**;

FIG. **15** is a perspective view of coils of one phase making up single-slot type coils of plural phases; and

FIG. **16** is a perspective view of coils of one phase making up triple-slot type coils of plural phases.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, an embodiment of the invention will be described by reference to the accompanying drawings. The drawings are to be seen in an orientation in which reference numerals given look properly.

As shown in FIGS. **1**, **2** and **5**, a stator **10** for an electric rotary machine according to this embodiment includes a stator core assembly **20** and a pair of base plate assemblies **30**L, **30**R, and the base plate assemblies **30**L, **30**R are disposed and assembled individually to ends of the stator core assembly **20**. An insulation sheet **65** which is made of, for example, silicone is disposed between the stator core assembly **20** and each of the base plate assemblies **30**L, **30**R to insulate the stator core assembly **20** and the base plate assemblies.

The stator core assembly **20** includes a stator core **21** and plural (48 in the embodiment shown in the figures) coil bars **25**.

The stator core **21** is made up, for example, of plural silicon steel sheets which are blanked out by a blanking press and, are laminated together and includes 48 teeth **22** which are provided on a radially inner side thereof and 48 slots **23** which are formed between the teeth **22**, **22** which lie adjacent to each other. The slots **23** are formed so as to penetrate the stator core **21** in an axial direction thereof and have a substantially elliptic shape which is elongated in a radial direction of the stator core **21** when viewed from the axial direction thereof. The slots **23** also have opening portions **24** which are opened to an inner circumferential surface of the stator core **21**.

Also, referring to FIG. **4**, the coil bar **25** includes a radially outer coil bar **26** and a radially inner coil bar **27** which have

the same shape and length. The radially outer coil bar **26** and the radially inner coil bar **27** are disposed parallel while being offset from each other in the axial direction by such an extent as a thickness of a connection coil **40**, which will be described later. The radially outer coil bar **26** and the radially inner coil bar **27** are formed integrally by being covered on the periphery thereof by an insulation material **28** which is injection molded from a resin, with both ends of each coil bar left uncovered. Specifically, the length of each of the radially outer coil bar **26** and the radially inner coil, bar **27** is set to a length which is substantially equal to a sum of an axial length of the stator core **21** and a thickness of three connection coils **40**, and small-diameter portions **26***a*, **27***a* are formed at both the ends of the radially outer coil bar **26** and the radially inner coil bar **27**, respectively, the length of the small-diameter portions **26***a*, **27***b* being substantially equal to the thickness of the connection coil **40**.

The plural (48 in the embodiment shown in the figures) coil bars **25**, each made up of the radially outer coil bar **26** and the radially inner coil bar **27**, are, as shown in FIG. **5**, inserted individually in the 48 slots **23** in the stator core **21** so that the radially outer coil bars **26** are situated radially outwards and are then aligned in a circumferential direction of the stator core **21**. Thus, the plural coil bars **25** make up the stator core assembly **20**.

The radially outer coil bars **26** are inserted individually in the slots **23** so that the small-diameter portion **26***a* projects approximately by such an extent as a thickness of two connection coils **40** from one end face **21***a* (a left end face in FIG. **5**) of the stator core **21**, while the small-diameter portion **26***a* projects approximately by such an extent as the thickness of the connection coil **40** from the other end face **21***b* (a right end face in FIG. **5**)

Additionally, the radially inner coil bars **27** are inserted individually in the slots **23** so that the small-diameter portion **27***a* projects approximately by such an extent as the thickness of the connection coil **40** from the one end face **21***a* of the stator core **21**, while the small-diameter portion **26***a* projects approximately by such an extent as the thickness of two connection coils **40** from the other end face **21***b*. The insulation material **28** is interposed between the radially outer coil bar **26** and the radially inner coil bar **27** and the slot **23** in the stator core **21** so as to ensure the insulation between the radially outer and inner coil bars **26**, **27** and the stator core **21**. Consequently, the radially outer coil bar **26** and the radially inner coil bar **27** are covered by the insulation member **28** in such a state that the radially outer and inner coil bars **26**, **27** are offset from each other in the axial direction so that the axial positions of the end portions thereof differ from each other.

The insulation material **28** which covers the radially outer coil bar **26** and the radially inner coil bar **27** has substantially the same shape as that of the slot **23** and is sized slightly larger than the slot **23**. Thus, the insulation material **28** can easily be inserted in the slot **23** through press fitting. In addition, the radially outer coil bar **26** and the radially inner coil bar **27** are thicker than a conventional coil which is made up of a winding which is wound therearound, and hence, there is provided an advantage that the space factor relative to the slot **23** is increased.

As shown in FIGS. **1** to **7**, the base plate assemblies **30**L, **30**R which are disposed individually at the ends of the stator core assembly **20** include base plates **31**L, **31**R and plural connection coils **40**. The base plate assembly **30**R differs from the base plate assembly **30**L in that the former does not include a connecting terminal portion, which will be described later, and in that the shapes of grooves formed and the connection coils provided on the former differ from those of the latter. The other configurations of both the base plate assemblies are the same, and therefore, the base plate assembly **30**L will mainly be described hereinafter.

As shown in FIGS. **6** and **7**, the base plate **31**L is formed from a resin having insulating properties and is a substantially annular member having substantially the same inside and outside diameters as those of the stator core **21**. A deployment portion **31***a* is provided at an upper portion of the base plate **31**L as seen in the figures so as to extend radially outwards therefrom into the shape of a segment. A connecting terminal portion is formed on the deployment portion **31***a* for connection to external equipment or the like.

48 pairs of radially outer through holes **32** and radially inner through holes **33** are formed to penetrate the base plate **31**L at a radially inner side of the base plate **31**L so a correspond, respectively, to the radially outer coil bars **26** and the radially inner coil bars **27** of the coil bars **25** which are inserted in the slots **23** in the stator core **21**.

The radially outer through hole **32** and the radially inner through hole **33** which make a pair are situated on the same straight line L which extends from a center O of the base plate **31** in a radial direction. Further, a radially outermost hole **34** is formed on an outside diameter side of the base plate **31**L. Thus, the radially outer and inner through holes **32**, **33** and radially outermost hole **34** establish a communication between an outer surface **35** and an inner surface **36** of the base plate **31**L (refer to FIG. **5**). Additionally, in a circumferential position where the deployment portion **31***a* is formed, 12 connecting terminal joining holes **39** are formed which are situated further radially outwards than the position of the radially outermost hole **34** in the deployment portion **31***a*.

As shown in FIGS. **5** to **7**, plural (48) outer surface grooves **37** and inner surface grooves **38** are formed along involute curves so as to lie close to one another on the outer surface **35** and the inner surface **36** of the base plate **31**L, respectively. The outer surface grooves **37** and the inner surface grooves **38** are formed to have a U-shaped section which is opened to the outer surface **35** and the inner surface **36**, respectively. The adjacent outer surface grooves **37** and the adjacent inner surface grooves **38** are isolated by walls **31***b* which is erected from the base plate **31**L, and the outer surface groves **37** and the inner surface grooves **38** which face each other in an axial direction are isolated by a bulkhead **31***c*, whereby the outer surface grooves **37** and the inner surface grooves **38** are electrically insulated one by one.

In addition, the base plate **31** is given an axial width which is substantially equal to a sum of groove depths of the outer surface groove **37** and the inner surface groove **38** which correspond, respectively, to an outer connection coil **41** and an inner connection coil **42**, which will both be described later, and a thickness of the bulkhead **31***c*.

In the base plate assembly **30**L, as shown in a front view of the base plate in FIG. **6**, each outer surface groove **37** on the base plate **31**L is formed in a curved fashion along the involute curve so as to connect one radially outer through hole **32** with one radially outermost hole **34** which is formed on a straight line L which passes through a radially outer through hole **32** which lies three radially outer through holes ahead in a clockwise direction from the one radially outer through hole **32**. In the plural outer surface grooves **37**, however, 12 outer surface grooves **37***a* which extend towards the deployment portion **31***a* extend in an involute fashion from the corresponding radially outer through holes **32** to straight lines L which pass through the radially outer through holes **32** which lie three radially outer through holes ahead in the clockwise direction from the radially outer through holes **32** from which

the outer surface grooves **37***a* start to extend and thereafter are bent radially outwards so as to connect to the corresponding connecting terminal joining holes **39**.

As shown in a rear view of the base plate in FIG. **7**, each inner surface groove **38** on the base plate **31** is formed in such a curved fashion as to avoid the interference with the corresponding radially outer through hole **32** so as to connect one radially inner through hole **33** with one radially outermost hole **34** which is formed on a straight line L which passes through a radially inner through hole **33** which lies three radially inner through holes ahead in a clockwise direction (in a counterclockwise direction when seen from the front side of the base plate **31**L shown in FIG. **6**) from the one radially inner through hole **33**. In the plural inner surface grooves **38**, however, 12 inner surface grooves **38***a* which extend towards the deployment portion **31***a* extend similarly in a curved fashion from the corresponding radially inner through holes **33** to straight lines L which pass through the radially inner through holes **33** which lie three radially inner through holes ahead in the clockwise direction (in the counterclockwise direction when seen from the front side of the base plate **31**L shown in FIG. **6**) from the radially inner through holes **33** from which the inner surface grooves **38***a* start to extend and thereafter are bent radially outwards so as to connect to the corresponding connecting terminal joining holes **39**.

Namely, as shown in FIG. **6**, the radially outer through hole **32** and the radially inner through hole **33** which are spaced six radially outer or inner through holes apart from each other in the clockwise direction (or in the counterclockwise direction) are connected to each other via the radially outermost hole **34** to which the outer surface groove **37** and the inner surface groove **38** commonly connect. In addition, the pair of outer surface groove **37***a* and inner surface groove **38***a* which connect to the common connecting terminal joining hole **39** connect the radially outer through hole **32** with the radially inner through hole **33** which are spaced six radially outer or inner through holes apart from each other in the clockwise direction (or in the counterclockwise direction).

In the base plate assembly **30**R, each outer surface groove **37** on the base plate **31**R has the same shape of each inner surface groove **38** on the base plate **31**L, and each inner surface groove **38** on the base plate **31**R has the same shape as each outer surface groove **37** on the base plate **31**L.

The connection coil **40** is formed of a conductive material such as copper into the shape of a plate. The connection coils **40** are divided into outer connection coils **41** (**41***a*, **41***b*) which are inserted in the outer surface grooves **37**, **37***a* and inner connection coils **42** (**42***a*, **42***b*) which are inserted in the inner surface grooves **38**, **38***a*. When referred to herein, the outer connection coils **41** are the connection coils **40** which are disposed on an axially outer side of the stator **10** when the stator core assembly **20** and the base plate assemblies **30** are assembled together, and the inner connection coils **42** are the connection coils **40** which are disposed on an axially inner side of the stator **10**.

As shown in FIG. **6**, the outer connection coils **41***a* are formed along the involute curves having the same shape of the outer surface grooves **37**, and connection holes **43***a*, **43***b* are formed at both end portions of the outer connection coils **41***a*. The connection hole **43***a* has a diameter which is substantially the same as that of the small-diameter portion **26***a* of the radially outer coil bar **26**, and the connection hole **43***b* has a diameter which is substantially the same as that of a connecting pin **45**, which will be described later, for connecting together the outer connection coil **41***a* and the inner connection coil **42***a*. In addition, the outer connection coils **41***b* are formed in a curved fashion to have the same shape as that of the outer surface grooves **37***a*, and connection holes **43***a* and connecting terminal holes **43***c* are formed at both end portions of the outer connection coils **41***b*.

As shown in FIG. **7**, the inner connection coils **42***a* are formed along the involute curves having the same shape of the inner surface grooves **38**, and connection holes **44***a*, **44***b* are formed at both end portions of the inner connection coils **42***a*. The connection hole **44***a* has a diameter which is substantially the same as that of the small-diameter portion **27***a* of the radially inner coil bar **27**, and the connection hole **44***b* has a diameter which is substantially the same as that of the connecting pin **45**. In addition, the inner connection coils **42***b* are formed in a curved fashion to have the same shape as that of the inner surface grooves **38***a*, and connection holes **44***a* and connecting terminal holes **44***c* are formed at both end portions of the inner connection coils **42***b*.

Consequently, except for the portion of the base plate **31**L where the connecting terminal joining holes **39**, the inner connection coils **42***a* and the outer connection coils **41***a*, **41***b* that are all connected to the radially outer coil bars **26** are formed along the involute curves, and the inner connection coils **42***a*, **42***b* and the outer connection coils **41***a* that are all connected to the radially inner coil bars **27** are formed along the involute curves so as to extend radially outwards from the radially inner through holes **33** on a radially inner side of the involute curves.

The outer connection coils **41***a*, **41***b* are inserted in the outer surface grooves **37**, **37***a*, respectively, and the inner connection coils **42***a*, **42***b* are inserted in the inner surface grooves **38**, **38***a*, respectively. The conductive connecting pins **45** which are made of copper or aluminum are inserted in the radially outermost holes **34** so as to electrically connect the outer connection coils **41***a* and the inner connection coils **42***a*.

By so doing, the base plate assemblies **30**L, **30**R are built up in such a state that the connection holes **43***a* of the outer connection coils **41***a* and the connection holes **44***a* of the inner connection coils **42***a* which are disposed six connection holes apart from each other in the clockwise direction (or in the counterclockwise direction) are electrically connected via the outer connection coils **41***a*, the connecting pins **45** and the inner connection coils **42***a*.

In place of providing the connecting pins **45** as in this embodiment, a configuration may be adopted in which projecting portions having the same shape of the connecting pin **45** are formed integrally on either of the outer connection coils **41***a* and the inner connection coils **42***a*, so that the projecting portions so formed are inserted in connection holes **43***b*, **44***b* which are provided on the other of the outer connection coils **41***a* and the inner connection coils **42***a*, whereby the outer connection coils **41***a* and the inner connection coils **42***a* are electrically connected to each other.

The pair of base plate assemblies **30**L, **30**R, which are configured as has been described heretofore, are disposed in the predetermined positions on both the ends of the stator core assembly **20** so as to be assembled thereto. As shown in FIG. **5**, in the base plate assembly **30**L which is disposed at the one end face **21***a* (the left end face in the figure) of the stator core **21**, the small-diameter portions **26***a* of the radially outer coil bars **26** are inserted in the connection holes **43***a* of the outer connection coils **41***a*, **41***b*, and the small-diameter portions **27***a* of the radially inner coil bars **27** are inserted in the connection holes **44***a* of the inner connection coils **42***a*, **42***b*. Thereafter, the small-diameter portions **26***a*, **27***a* are crimped to be fixed in place in the corresponding connection holes **43***a*, **44***a*. Namely, the outer connection coils **41***a*, **41***b* and the inner connection coils **42***a*, **42***b* connect together the coil bars

25 of the same phase (for example, a U-phase) to thereby form extending portions of a coil **50**.

In the base plate assembly **30**R which is disposed at the other end face **21***b* (the right end face in the figure) of the stator core **21**, the small-diameter portions **26***a* of the radially outer coil bars **26** are inserted in the connection holes **44***a* of the inner connection coils **42***a*, and the small-diameter portions **27***a* of the radially inner coil bars **27** are inserted in the connection holes **43***a* of the outer connection coils **41***a*. Thereafter, the small-diameter portions **26***a*, **27***a* are crimped to be fixed in place in the corresponding connection holes **43***a*, **44***a*. Namely, the outer connection coils **41***a* and the inner connection coils **42***a* connect together the coil bars **25** of the same phase (for example, the U-phase) to thereby form extending portions of the coil **50**.

Consequently, with respect to the radially outer coil bar **26** and the radially inner coil bar **27** which are disposed in the same slot **23**, the outer connection coil **41***a* which is connected to the one end (the left end in the figure) of the radially outer coil bar **26** extends radially outwards and in the clockwise direction to connect to the inner connection coil **42***a* of the same phase, while the inner connection coil **42***a* which is connected to the other end (the right end in the figure) of the radially outer coil bar **26** extends radially outwards and in the counterclockwise direction to connect to the outer connection coil **41***a* of the same phase. In addition, the inner connection coil **42***a* which is connected to the one end (the left end in the figure) of the radially inner coil bar **27** extends radially outwards and in the counterclockwise direction to connect to the outer connection coil **41***a* of the same phase, while the outer connection coil **41***a* which is connected to the other end (the right end in the figure) of the radially inner coil bar **27** extends radially outwards and in the clockwise direction to connect to the inner connection coil **42***a* of the same phase.

In this way, the stator **10** is made up by assembling the pair of base plate assemblies **30**L, **30**R to both the ends of the stator core assembly **20**, whereby segmented coils **50** make up four coil loops for each phase which has the same construction (U-phase coils **50**U, V-phase coils **50**V, and W-phase coils **50**W). In these coil loops of the three phases (the U-phase coils **50**U, the V-phase coils **50**V, and the W-phase coils **50**W), two coil loops make up a set, and hence, two sets of U-phase coils **50**U, two sets of V-phase coils **50**V, and two sets of W-phase coils **50**W are wave wound in the counterclockwise direction in this order (refer to FIGS. **8** and **10**). Then, the radially outer coil bar **26** and the radially inner coil bar **27** which are covered together by the insulation material **28** to be disposed within the same slot **23** each include two coils which make up one set. FIG. **8** is a perspective view of double-slot type, segmented coils of plural phases (U-, V- and W-phase) which are taken out from the stator for better understanding, and FIG. **9** is a perspective view of coils of one phase (for example, U-phase) which are taken out, in turn, from the coils of the plural phases. FIG. **10** is an exemplary diagram showing the configuration of the coils of the plural phases, FIG. **11**A is a partial enlarged view of FIG. **6**, and FIG. **11**B is a sectional view taken along the line B-B in FIG. **11**A.

Additionally, in the stator **10** which is configured in the way described heretofore, the outer connection coils **41***a*, **41***b* and the inner connection coils **42***a*, **42***b* are disposed within a region where the stator core **21** is projected in the axial direction and are disposed in different positions with respect to the axial direction.

In the sectional view of the base plate assembly **30**L taken along the line B-B which is shown in FIG. **11**A, as shown in FIG. **11**B, on the outer surface of the base plate **31**L, two V-phase outer connection coils **41***b* and one W-phase outer connection coil **41***b* are aligned in this order from in a radially inward to outward direction at the small-diameter portion **26***a* of the U-phase radially outer coil bar **26** from a radially inner side, while on the inner surface of the base plate **31**L, one U-phase connection coil **42***b* and two W-phase inner connection coils **42***b* are aligned in this order from the radially inner. Consequently, as is clear from FIG. **11**A, the inner connection coils **42***a*, **42***b* face the outer connection coils **41***a*, **41***b* of the different phase in the axial direction, and the outer connection coils **41***a*, **41***b* face the inner connection coils **42***a*, **42***b* of the different phase in the axial direction.

In addition, outer surfaces of the plural outer connection coils **41***a*, **41***b* which are disposed at the axially outer ends of the stator **10** are level with the end faces of the base plates **31**L, **31**R.

Additionally, as is shown in FIG. **5**, the coils **50** are assembled to the stator **10** so that the outer connection coils **41***a*, **41***b* which connect to the radially outer coil bars **26** are situated axially outwards at the one end face **21***a* of the stator core **21**, while at the other end face **21***b* of the stator core **21**, the outer connection coils **41***a* which connect to the radially inner coil bars **27** are situated axially outwards.

FIGS. **12**A to **12**C show conceptual diagrams showing connecting constructions between a coil bar and connection coils. Hereinafter, the radially outward coil bar **26** is taken as an example for description. However, connecting constructions which will be described below can also be applied to the radially inner coil bar **27**. In a radially outer coil bar **26** shown at FIG. **12**A, tapered portions **26***b* which are tapered towards ends of the radially outer coil bar **26** are formed at both end portions, and a connection hole **43***a* in an outer connection coil **41***a* or **41***b* and a connection hole **44***a* in an inner connection coil **42***a* are made into a tapered hole having a gradient which is substantially equal to that of the end portions of the radially outer coil bar **26**. The radially outer coil bar **26** and the connection coils **40** are assembled together so that the base plates **31**L, **31**R are assembled to the stator core **21** and the connection coils **90** are then pressed axially relative to the radially outer coil bar **26** by pressing members **61** of jigs by virtue of elastic forces of springs **64**, whereby the connection holes **43***a*, **44***a* of the connection coils **40** are fitted on the tapered portions **26***b* of the radially outer coil bar **26**. Then, the end portions of the radially outer coil bar **26** are crimped by being crushed to be deformed at ends by a punch **62**, whereby the coil bar **26** and the connection coils **40** are fixed together.

As this occurs, the fitting portions between the radially outer coil bar **26** and the connection coils **40** are tapered, and therefore, even in case centers of the radially outer coil bar **26** and the connection coils **40** are offset slightly, the radially outer coil bar **26** and the connection coils **40** are centered by virtue of pressures applied thereto by the pressing members **61** so that the radially outer coil bar **26** and the connection coils **40** are joined together at the tapered portions **26***b* in an ensured fashion to thereby establish an electric communication therebetween. In addition, such joining can be executed at plural locations (96 locations in this embodiment) through a single pressing operation. Thus, the joining work can be executed efficiently, thereby making it possible to increase the fabrication efficiency remarkably. It should be noted that the coil bar **25** and the connection coils **40** do not necessarily have to be connected together by press fitting and crimping, and hence, they may be connected together by press fitting or crimping. Thus, a connection of the coil bar **25** and the connection coils **40** based on press fitting will be described below.

End portions of a radially outer coil bar **26**, shown in FIG. **12**B, are formed into a semi-spherical shape, and connection holes **43***a*, **44***a* of connection coils **40** are formed into a semi-spherical depressed portion. In this construction, the semi-spherical end portions of the radially outer coil bar **26** are press fitted in the connection holes **43***a*, **44***a* of the connection coils **40**, whereby the radially outer coil bar **26** and the connection coils **40** are joined together. In this construction, too, the radially outer coil **26** and the connection coils **40** can be centered. In addition, such joining can be executed at plural locations through a single pressing operation, whereby the radially outer coil **26** and the connection coils **40** can be joined together extremely efficiently.

A radially outer coil bar **26**, shown in FIG. **12**C, is formed to have a rectangular cross section, and end portions thereof are formed into a semicircular shape. In addition, connection holes **43***a*, **44***a* of connection coils **40** are similarly formed into a semicircular depressed portion, and the radially outer coil bar **26** and the connection coils **40** are joined together by press fitting the end portions of the radially outer coil **26** into the connection holes **43***a*, **44***a* which are the semicircular depressed portions. Being given the rectangular cross section, the radially outer coil bar **26** of this embodiment has an angular shape which closely matches that of the slot **23**, and therefore, the space factor of the slot **23** can also be enhanced.

FIG. **13** is a perspective view of the stator in which cooling plates are disposed at end faces of the base plate assemblies, and FIG. **14** is a vertical sectional view of a main part of the stator. As shown in FIGS. **13** and **14**, a pair of cooling plates **60** are disposed so as to be in contact with the base plate assemblies **30** which are provided at both the end faces of the stator **10**. A refrigerant passageway **63** is formed in an interior of the cooling plate **60** so that a refrigerant is allowed to circulate therein. Then, a refrigerant which is sent under pressure from a refrigerant supply system, not shown, is circulated in, for example, a direction indicated by an arrow C (refer to FIG. **13**) in the refrigerant passageway **63** in the cooling plate **60**. Thus, the stator **10** can be cooled positively via the outer connection coils **41***a*, **41***b* (the extending portions) of the stator **10** with which the pair of cooling plates **60** are in contact.

Additionally, front surfaces of the outer connection coils **41***a*, **41***b* are flat, and therefore, the outer connection coils **41***a*, **41***b* are brought into surface contact with the cooling plates **60**. Because of this, compared with a conventional coil around which a winding is wound, the contact area with the cooling plates **60**, that is, the heat conduction area is large, thereby making it possible to cool the stator **10** efficiently.

Additionally, in the coils **50**, at the one end face **21***a* of the stator core **21**, the outer connection coils **41***a*, **41***b* which connect to the radially outer coil bars **26** are situated axially outwards, while at the other end face **21***b* of the stator core **21**, the outer connection coils **41***a* which connect to the radially inner coil bars **27** are situated axially outwards. Therefore, the radially outer coil bars **26** and the radially inner coil bars **27** are cooled uniformly via the outer connection coils **41***a*, **41***b* to thereby suppress the heat distribution of the coils. Further, the coils **50** are free from concerns caused when an oil cooling process using an ATF oil or the like is selected that the coils and the insulation materials are badly affected by the ATF oil which is sprayed to the coils, the reliability and durability of the stator being thereby enhanced.

Thus, as has been described heretofore, the stator **10** according to this embodiment includes the stator core **21** and the segmented coils **50** of plural phases, and the segmented coils **50** of plural phases have the plural coil bars **25** which are inserted individually in the plural slots **23** in the stator core **21** and which extend substantially in the straight line and the plural connection coils **40** which connect together the coil bars **25** of the same phase to thereby make up the extending portions. The connection coils **40** each includes the inner connection coil **42** and the outer connection coil **41** which are disposed in the different axial positions, and the inner connection coil **42** faces the outer connection coil **91** of the different phase in the axial direction, while the outer connection coil **41** faces the inner connection coil **42** of the different phase in the axial direction. Therefore, the extending portions which connect together the coil bars **25** of the same phase are disposed in the different axial positions, whereby the axial projection of the extending portions can be suppressed, thereby making it possible to reduce the size of the stator **10**. In addition, the copper loss can be suppressed as a result of the length of the extending portions being reduced, the performance of the electric rotary machine being thereby enhanced.

In addition, the pair of base plates **31**L, **31**R are provided at both the ends of the stator core **21**, and in each of the pair of base plates **31**L, **31**R, the plural grooves **37**, **38** are formed on the outer surface **35** and the inner surface **36** thereof which face each other, respectively. The outer connection coils **41** are disposed in the grooves **37** which are formed on the outer surface **35**, while the inner connection coils **42** are disposed in the grooves **38** which are formed on the inner surface **36**. Therefore, the extending portions are disposed in the different axial positions efficiently in such estate that the extending portions are insulated by each of the base plates **31**L, **31**R, whereby not only can the size of the stator **10** be reduced, but also the assembling properties of the segmented coils **50** can be enhanced.

Further, the coil bars **25** which are inserted individually in the slots **23** each include the radially outer coil bar **26** and the radially inner coil bar **27** which are aligned in the radial direction, and the radially outer coil bar **26** is connected to the outer connection coil **41** at one end and is connected to the inner connection coil **42** at the other end thereof, while the radially inner coil bar **27** is connected to the inner connection coil **42** at one end and is connected to the outer connection coil **41** at the other end thereof. Therefore, the outer and inner connection coils **41**, **42** can be connected to the two coil bars **26**, **27** which extend from the slot **23** in the form of a wave winding.

In addition, the radially outer coil bar **26** and the radially inner coil bar **27** are connected to the outer connection coils **41** which are positioned axially outwards of the stator **10** on either end face of the stator core **21**. By adopting this configuration heat generated in the stator **10** is dissipated via the outer connection coils **41**, thereby making it possible to cool the radially outer coil bar **26** and the radially inner coil bar **27** uniformly. The stator **10** can be cooled further efficiently when the cooling plates **60** are disposed so as to be in contact with the outer connection coils **41** which are situated at the axial outer ends of the stator **10**.

Additionally, the outer connection coil **41** connected to the radially outer coil bar **26** at the one end thereof extends radially outwards and in one of the clockwise direction and the counterclockwise direction to thereby be connected to the inner connection coil **42** of the same phase, the inner connection coil **42** connected to the radially outer coil bar **26** at the other end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to the outer connection coil **41** of the same phase, the inner connection coil **42** connected to the radially inner coil bar **27** at the one end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to

the outer connection coil **41** of the same phase, and the outer connection coil **41** connected to the radially inner coil bar **27** at the other end thereof extends radially outwards and in the one of the clockwise direction and the counterclockwise direction to thereby be connected to the inner connection coil **42** of the same phase. By adopting this configuration, the outer and inner connection coils **41**, **42** can be connected to the coil bars **26**, **27** which extend from the slot **23** radially outwards of the outer and inner coil bars **26**, **27**, and the rotor can easily be disposed inside the stator **10**, thereby making it possible to connect the connection coils **40** with the coil bars **25** in the form of a wave winding.

Additionally, in each of the base plates **31**L, **31**R, the radially inner through hole **33** and the radially outer through hole **32** in which the radially inner coil bar **27** and the radially outer coil bar **26** which are disposed in the same slot **23** in the stator core **21** are inserted, respectively, are formed so as to be aligned in the radial direction, and the inner connection coil **42** and the outer connection coil **41** which are connected to the radially outer coil bar **26** are formed so as to extend along the involute curve. Further, the inner connection coil **42** and the outer connection coil **41** which are connected to the radially inner coil bar **27** are formed so as to extend along the involute curve while being bent on the radially inner side of the involute curve so as to extend radially outwards from the radially inner through hole **33** while extending around the radially outer through hole **32**. Therefore, the inner connection coil **42** and the outer connection coil **41** do not interfere with each other within each of the base plates **31**L, **31**R, thereby making it possible to reduce the area occupied by them.

In addition, the radially outer coil bar **26** and the radially inner coil bar **27** are made to have the same length, whereby parts for coil bars **25** can be commonized.

Additionally, the plural connection coils **40** are disposed within the region where the stator core **21** is projected in the axial direction, and therefore, the size of the stator **10** in the radial direction can be reduced. Additionally, the rotor can easily be disposed inside the stator **10**.

It should be noted that the invention is not limited to the embodiment that has been described heretofore and hence can be modified or improved as required.

For example, in the embodiment, 12 connecting terminal joining holes **39** are formed. However, the invention is not limited thereto, and hence, a configuration may be adopted in which six connecting terminal joining holes **39** are formed, and adjacent connection coils of the same phase are connected together.

Additionally, an insulation cover may be disposed at the axially outer ends of the pair of base plate assemblies **30**L, **30**R. Alternatively, the axially outer ends may be covered with a resin or the like.

The stator **10** of the invention is not limited to the double-slot type stator that has been described above. For example, the stator **10** can be configured as a single-slot type stator of which the shape of coils of one phase is shown in FIG. **15** or can be configured as a triple-slot type stator of which the shape of coils of one phase is shown in FIG. **16**. In a three-phase, eight-pole, wave wound stator, in the case of the single-slot type stator, the number of slots in the stator core **21** is 24, and in the case of the triple-slot type stator, the number of slots in the stator core **21** is 72.

What is claimed is:

1. A stator for an electric rotary machine comprising:

a stator core having: a back yoke having a circular shape; a plurality of teeth extending in an inner radial direction of the back yoke; and a plurality of slots being provided between the plurality of teeth; and

segmented coils of a plurality of phases, wherein:

the segmented coils of a plurality of phases have pluralities of coil bars which are inserted individually in the plurality of slots in the stator core and which extend substantially in a straight line and pluralities of connection coils which connect together the coil bars of the same phase to thereby make up extending portions;

the connection coils each comprise an inner connection coil and an outer connection coil which are disposed in different axial positions, wherein the inner connection coil and the outer connection coil are disposed opposite each other on opposite ends of the stator core;

the inner connection coil faces an outer connection coil of a different phase in an axial direction and the outer connection coil faces the inner connection coil of a different phase in the axial direction;

one end of the inner connection coil and one end of the outer connection coil are connected to each other by a same coil bar at a plurality of connection holes on the inner connection coil bar and at a plurality of connection holes on the outer connection coil bar, and the other end of the inner connection coil and the other end of the outer connection coil extend in a radially outwards direction toward a position facing the back yoke in the axial direction;

the inner connection coil is electrically connected to the outer connection coil of the same phase in the radially outwards direction;

one of the coil bars is electrically connected to one of the coil bars of the same phase which is inserted into a different slot; and

the other end of the inner connection coil and the other end of the outer connection coil are connected with each other at the position facing the back yoke in the axial direction.

2. The stator core for an electric rotary machine according to claim **1**, wherein:

a pair of base plates are provided at both ends of the stator core;

in each of the pair of base plates, a plurality of grooves are formed on each of an outer surface and an inner surface thereof which face each other;

the outer connection coils are disposed in the grooves which are formed on the outer surface; and

the inner connection coils are disposed in the grooves which are formed on the inner surface.

3. The stator for an electric rotary machine according to claim **1**, wherein:

the coil bars which are inserted individually in the slots each comprise a radially outer coil bar and a radially inner coil bar which are aligned in a radial direction;

one of the radially outer coil bar and the radially inner coil bar is connected to the outer connection coil at one end and is connected to the inner connection coil at the other end thereof; and

the other of the radially outer coil bar and the radially inner coil bar is connected to the inner connection coil at one end and is connected to the outer connection coil at the other end thereof.

4. The stator for an electric rotary machine according to claim **3**, wherein:

the outer connection coil connected to the radially outer coil bar at the one end thereof extends radially outwards and in one of a clockwise direction and a counterclockwise direction to thereby be connected to an inner connection coil of the same phase;

the inner connection coil connected to the radially outer coil bar at the other end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to an outer connection coil of the same phase;

the inner connection coil connected to the radially inner coil bar at the one end thereof extends radially outwards and in the other of the clockwise direction and the counterclockwise direction to thereby be connected to an outer connection coil of the same phase; and

the outer connection coil connected to the radially inner coil bar at the other end thereof extends radially outwards and in the one of the clockwise direction and the counterclockwise direction to thereby be connected to an inner connection coil of the same phase.

5. The stator for an electric rotary machine according to claim **4**, wherein:

in each of the base plates, a radially inner through hole and a radially outer through hole in which the radially inner coil bar and the radially outer coil bar which are disposed in the same slot in the stator core are inserted, respectively, are formed so as to be aligned in the radial direction;

the inner connection coil and the outer connection coil which are connected to the radially outer coil bar are formed so as to extend along an involute curve; and

the inner connection coil and the outer connection coil which are connected to the radially inner coil bar are formed so as to extend along an involute curve while being bent at a radially inner end of the involute curve so as to extend radially outwards from the radially inner through hole while extending around the radially outer through hole.

6. The stator for an electric rotary machine according to claim **3**, wherein

the radially outer coil bar and the radially inner coil bar have the same length.

7. The stator for an electric rotary machine according to claim **1**, wherein

the pluralities of connection coils are disposed within a region where the stator core is projected in the axial direction.

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